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Understanding *Aedes aegypti* and climate in Latin America and the Caribbean

Anna M. Stewart Ibarra, PhD, MPA
Center for Global Health and Translational Science
SUNY Upstate Medical University

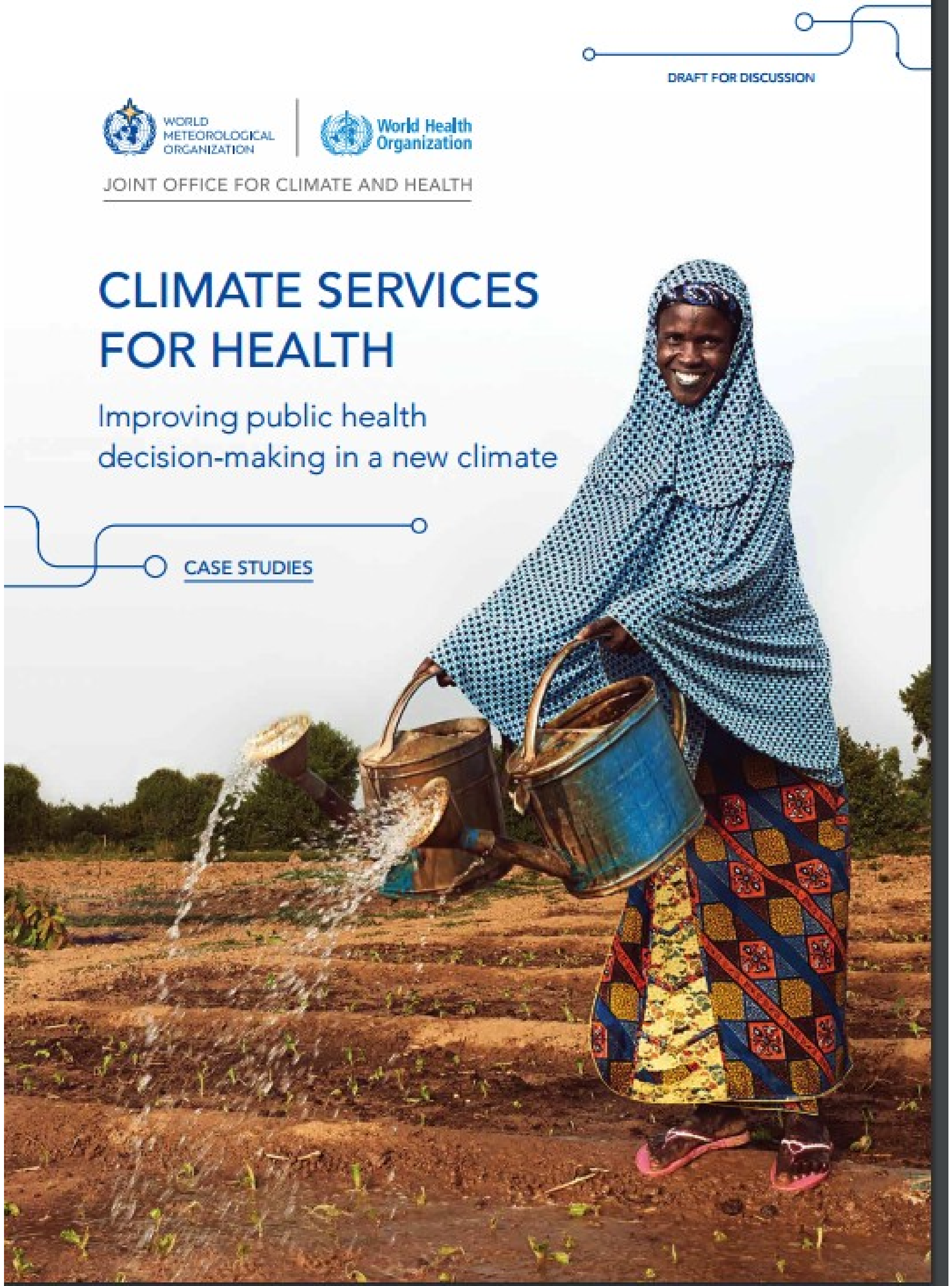
Webinar, June 9, 2017

In partnership with UPSTATE MEDICAL UNIVERSITY

“ Climate services are a new type of health service that can improve the effectiveness of our core business –detecting disease, monitoring health risks, anticipating problems, and taking action to save lives.”

- *Margaret Chan, WHO director general statement to the Intergovernmental Board on Climate Services, November 2014.*

“Currently, and despite wide recognition of the connections between climate and health, climate information and services to inform health decisions are not used to their full potential (Rogers et al. 2010).” from WHO/WMO, 2016 pg 9.



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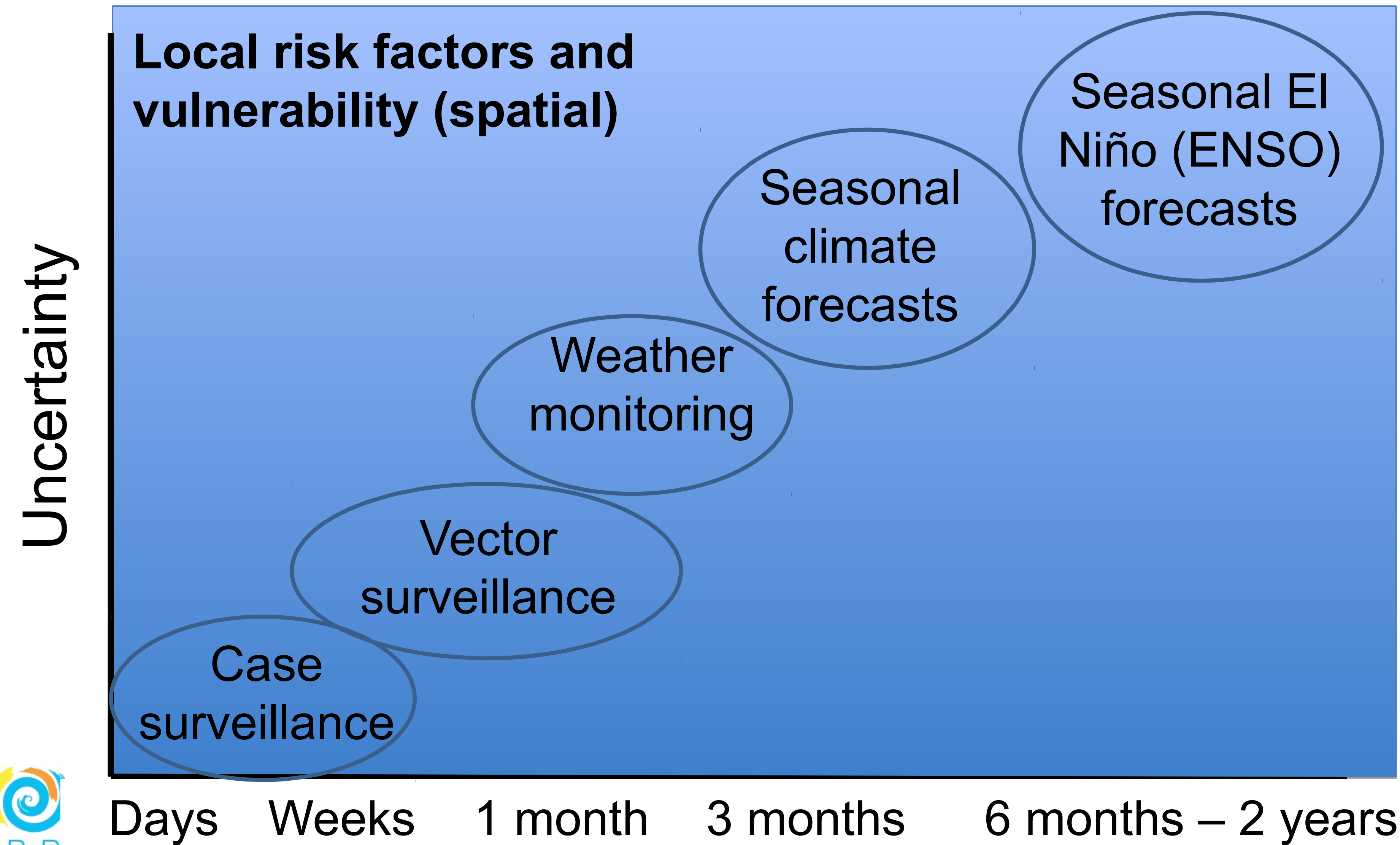
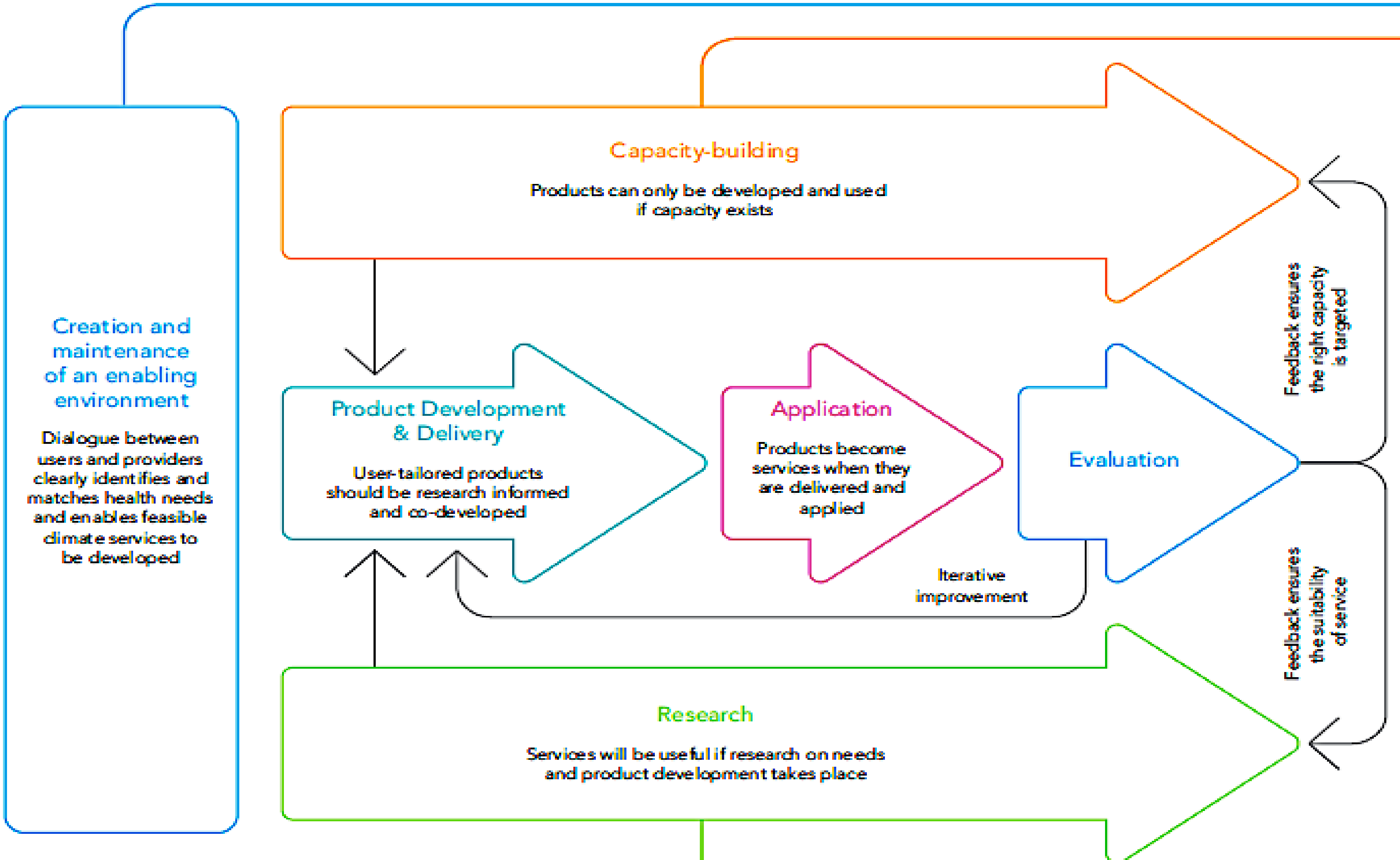
Early warning systems for epidemics



Early warning systems that use climate information are a strategy to better manage and prevent epidemics.

1. Bring together the climate-health sector and local communities.
2. Provide the evidence base that climate affects epidemics/outbreaks.
3. Strengthen local disease, mosquito, and climate surveillance systems. Match the spatial and temporal resolution of data.
4. Strengthen climate forecast models.
5. Create models to forecast epidemics using climate information.
6. Translate the models into useful/operational tools for the public health sector, which reflect the local reality.



(WHO/WMO 2016)

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Development of a health climate spatio-temporal modeling framework for the Caribbean

Aim: To collaborate with regional climate and health stakeholders in the Caribbean to develop a modeling framework that will ultimately provide spatio-temporal probabilistic forecasts of *Aedes aegypti* abundance, an indicator of the risk of transmission of dengue fever, zika fever, and chikungunya.

Case studies in Dominica and Barbados.

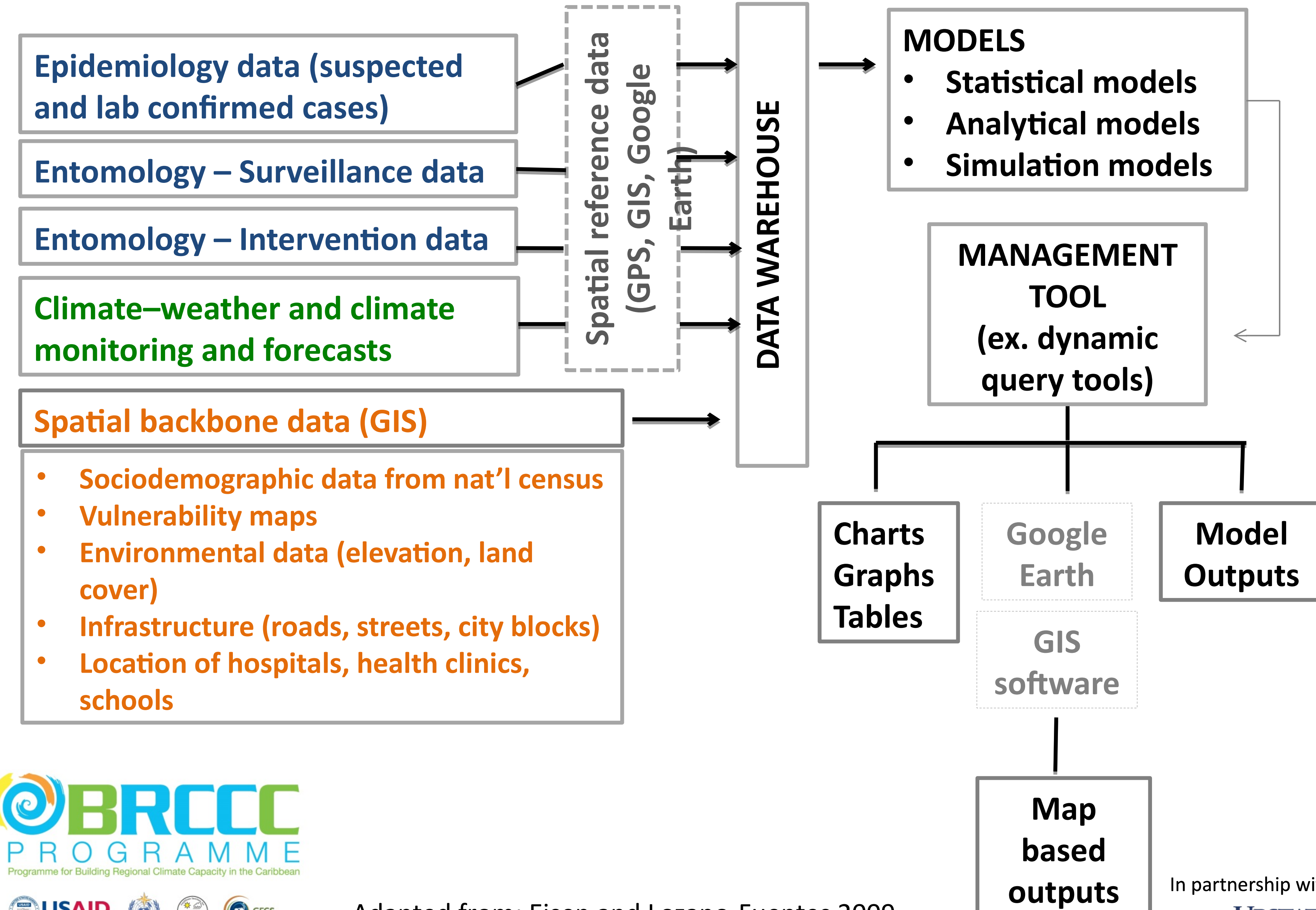
1. Stakeholder engagement: Conduct stakeholder mapping and a needs assessment of climate and health stakeholders.

2. Spatiotemporal modeling: Develop probabilistic (risk) maps of *Aedes aegypti* and evaluate statistical associations and lag periods among climate, *Aedes aegypti* and disease transmission.

3. Capacity strengthening: Webinar series on climate and health

Timeframe: February to July 2017:

ARBOVIRUS DECISION SUPPORT STSTEM



Adapted from: Eisen and Lozano-Fuentes 2009

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Dengue fever: genus *flavivirus*.

- Four serotypes of the virus (DENV1-4).
- Infection from one serotype results in immunity to that serotype. Infection with a second serotype results in more severe disease.
- Dengue vaccine (Sanofi Pasteur) with limited efficacy available in some countries.
- Disease ranges from mild to severe shock, hemorrhage, death.
- Current estimates of apparent DENV infection in Latin America range from 1.5 million to 13.3 million cases per year.

Chikungunya: genus *alphavirus*.

- No vaccine yet.
- Disease causes febrile illness similar to dengue and long-term joint pain.
- First cases reported in the Americas in 2013.
- Over 2 million cases to date.

Zika fever: genus *flavivirus*

- No vaccine yet.
- Disease causes febrile illness similar to dengue and can result in neurological complications including Guillain-Barré syndrome and congenital syndrome.
- First cases reported in Brazil in 2015. To date, 753,703 suspected and confirmed autochthonous cases of ZIKV have been reported from 48 countries and territories in the Americas.
- Zika can also be transmitted by sex, from mother to child during pregnancy, by blood transfusion, and laboratory transmission

Sexually transmitted zika:

Zika virus persists longer in semen than in other bodily fluids. Detection of Zika virus RNA in semen has been reported up to 188 days after illness onset.

https://www.cdc.gov/zika/hc-providers/clinical-guidance/sexualtransmission.html

Aedes aegypti: urban enemy

- Female mosquitoes are highly competent vectors of viruses that cause disease in humans: DENV, CHIKV, ZIKV, Mayaro, YFV
- The mosquito is highly invasive
- *Aedes aegypti* are day-time biters and prefer to feed on people (anthropophilic) in and around the home, school and workplace.
- Containers with standing water are used as larval habitat. Cryptic larval habitat is increasingly common (e.g., sewers, gutters, utility junction boxes).
- They are increasingly resistant to insecticide.
- Vector (mosquito) control is the primary way that the public health sector controls epidemics.

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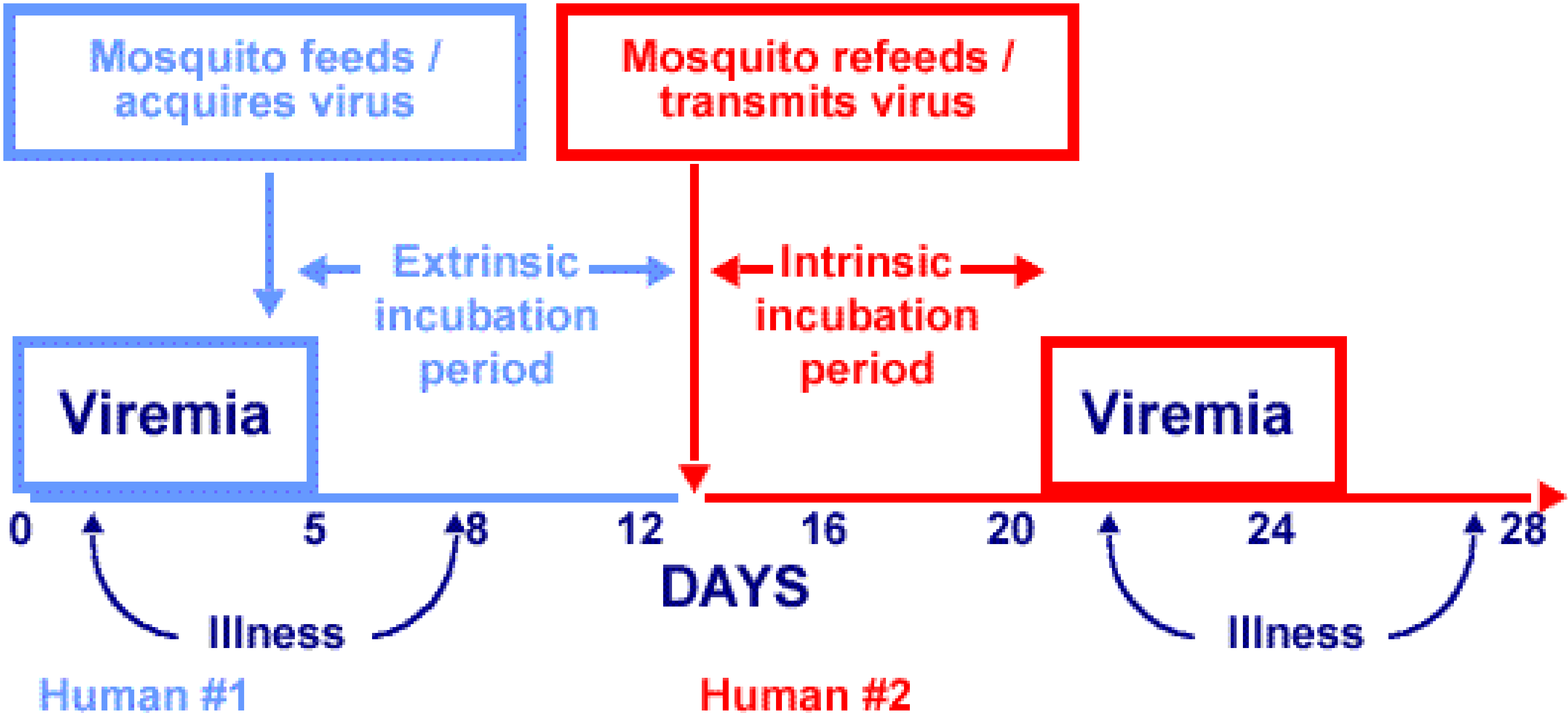
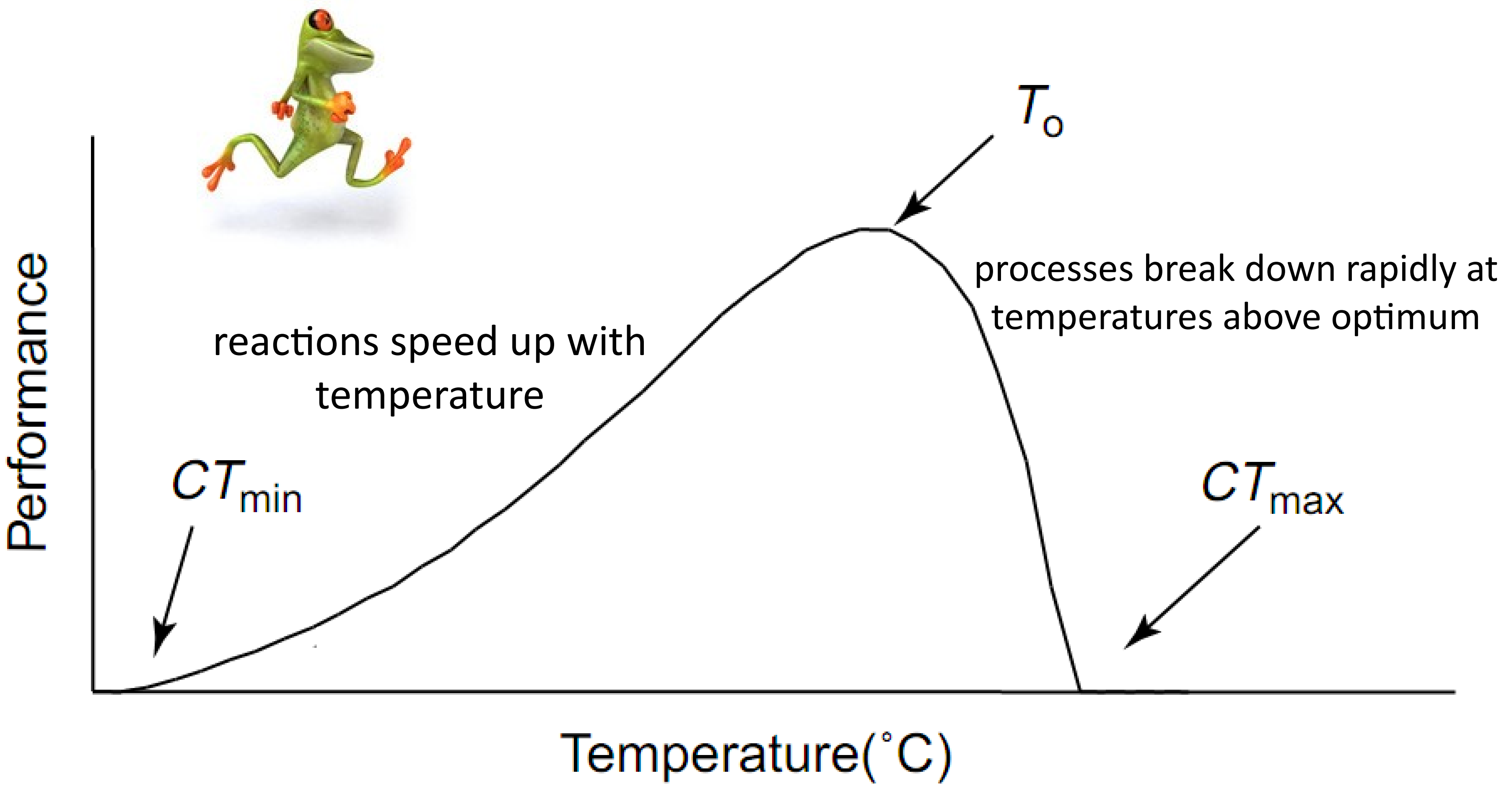
Transmission cycle



(CDC)

How Does Temperature Drive Biological Processes?



(From S. Ryan)

Aedes aegypti is sensitive to climate conditions

- Temperature affects mosquito physiology.
  - Warmer temperatures (up to an optimum) increase biting rates, faster larval development, shorter length of the EIP, shorter gonotrophic cycle, faster virus replication in the mosquito.
- Rainfall is more complicated.
  - More rainfall can increase containers outdoors filled with rain water = more larval habitat
  - Less rainfall can increase water storage containers filled with tap water = more larval habitat

PLOS | NEGLECTED TROPICAL DISEASES

RESEARCH ARTICLE

Detecting the impact of temperature on transmission of Zika, dengue, and chikungunya using mechanistic models

Erin A. Mordecai[1]*, Jeremy M. Cohen[2], Michelle V. Evans[3], Prithvi Gudapati[1], Leah R. Johnson[2,4], Catherine A. Lippi[5], Kerri Miazgowicz[6], Courtney C. Murdock[3,6], Jason R. Rohr[2], Sadie J. Ryan[5,7,8,9], Van Savage[10,11], Marta S. Shocket[1,12], Anna Stewart Ibarra[13], Matthew B. Thomas[14], Daniel P. Weikel[15]

Author summary

Understanding the drivers of recent Zika, dengue, and chikungunya epidemics is a major public health priority. Temperature may play an important role because it affects virus transmission by mosquitoes, through its effects on mosquito development, survival, reproduction, and biting rates as well as the rate at which mosquitoes acquire and transmit viruses. Here, we measure the impact of temperature on transmission by two of the most common mosquito vector species for these viruses, *Aedes aegypti* and *Ae. albopictus*. We integrate data from several laboratory experiments into a mathematical model of temperature-dependent transmission, and find that transmission peaks at 26–29°C and can occur between 18–34°C. Statistically comparing model predictions with recent observed human cases of dengue, chikungunya, and Zika across the Americas suggests an important role for temperature, and supports model predictions. Using the model, we predict that most of the tropics and subtropics are suitable for transmission in many or all months of the year, but that temperate areas like most of the United States are only suitable for transmission for a few months during the summer (even if the mosquito vector is present).

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The impact of climate on health depends on the social vulnerability of the population. **Risk factors for dengue**: housing conditions, access to/interruptions in piped water, water storage around the home, knowledge, attitudes, mosquito abatement practices, economic barriers, housing density, education/income levels.

Strengthening climate-health surveillance and research capacities in Ecuador

Aim: Create a long-term research platform for climate-sensitive diseases and other priority areas, e.g., other pathogens, clinical trials, vector control interventions.

Approach:

- Strong partnerships and an interdisciplinary and international research team
- A social-ecological systems approach to study design and analysis.
- Strengthening virus-vector-climate surveillance systems (diverse data streams) and ongoing training and capacity building
- Integration of data through spatiotemporal modeling.

Outcome:

- Generate the evidence base for the effects of climate on health
- Identify and test effective public health responses and interventions.

msp

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enfarma
EMPRESA PÚBLICA DE FÁRMACOS

ESCUELA SUPERIOR POLITECNICA DEL LITORAL
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PONTIFICIA UNIVERSIDAD CATÓLICA DEL ECUADOR
SERÉIS MIS TESTIGOS

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Hospital de Niños Dr. Roberto Gilbert Elizalde
H. Junta de Beneficencia de Guayaquil

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1969

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CORNELL UNIVERSITY FOUNDED A.D. 1865

Center for Global Health & Translational Science

SYRACUSE UNIVERSITY FOUNDED AD 1870
SUOS CULTORES SCIENTIA CORONAT

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Machala, Ecuador (~250,000 pop.)
Dengue is hyperendemic (DENV1-4)

Stakeholder engagement with communities, climate and health sectors.

Understand the needs, timeframe, expectations, expertise, and language of each group.

Analyses of stakeholder perceptions

Stewart Ibarra et al. BMC Public Health 2014, 14:1135
http://www.biomedcentral.com/1471-2458/14/1135

BMC Public Health

RESEARCH ARTICLE **Open Access**

A social-ecological analysis of community perceptions of dengue fever and *Aedes aegypti* in Machala, Ecuador

Anna M Stewart Ibarra[1,4*], Valerie A Luzadis[2], Mercy J Borbor Cordova[3], Mercy Silva[4], Tania Ordoñez[4], Efraín Beltrán Ayala[4,5] and Sadie J Ryan[1,6,7]

Handel et al. Tropical Diseases, Travel Medicine and Vaccines (2016) 2:8
DOI 10.1186/s40794-016-0024-y

Tropical Diseases
Travel Medicine and Vaccines

RESEARCH **Open Access**

Knowledge, attitudes, and practices regarding dengue infection among public sector healthcare providers in Machala, Ecuador

Andrew S. Handel[1], Efraín Beltrán Ayala[2,3], Mercy J. Borbor-Cordova[4], Abigail G. Fessler[5], Julia L. Finkelstein[5], Roberto Xavier Robalino Espinoza[3], Sadie J. Ryan[6,7,8] and Anna M. Stewart-Ibarra[7*]

International Journal of
Environmental Research and Public Health

Article

Household Dengue Prevention Interventions, Expenditures, and Barriers to *Aedes aegypti* Control in Machala, Ecuador

Naveed Heydari [1,2,*], David A. Larsen [3], Marco Neira [4], Efraín Beltrán Ayala [5], Prissila Fernandez [2], Jefferson Adrian [2], Rosemary Rochford [1] and Anna M. Stewart-Ibarra [2]

Krisher et al. Malar J (2016) 15:573
DOI 10.1186/s12936-016-1630-x

Malaria Journal

CASE STUDY **Open Access**

Successful malaria elimination in the Ecuador–Peru border region: epidemiology and lessons learned

Lyndsay K. Krisher[1], Jesse Krisher[2], Mariano Ambuludi[3], Ana Arichabala[3], Efrain Beltrán-Ayala[3,4], Patricia Navarrete[3], Tania Ordoñez[3], Mark E. Polhemus[2], Fernando Quintana[5], Rosemary Rochford[6], Mercy Silva[3], Juan Bazo[7] and Anna M. Stewart-Ibarra[2*]

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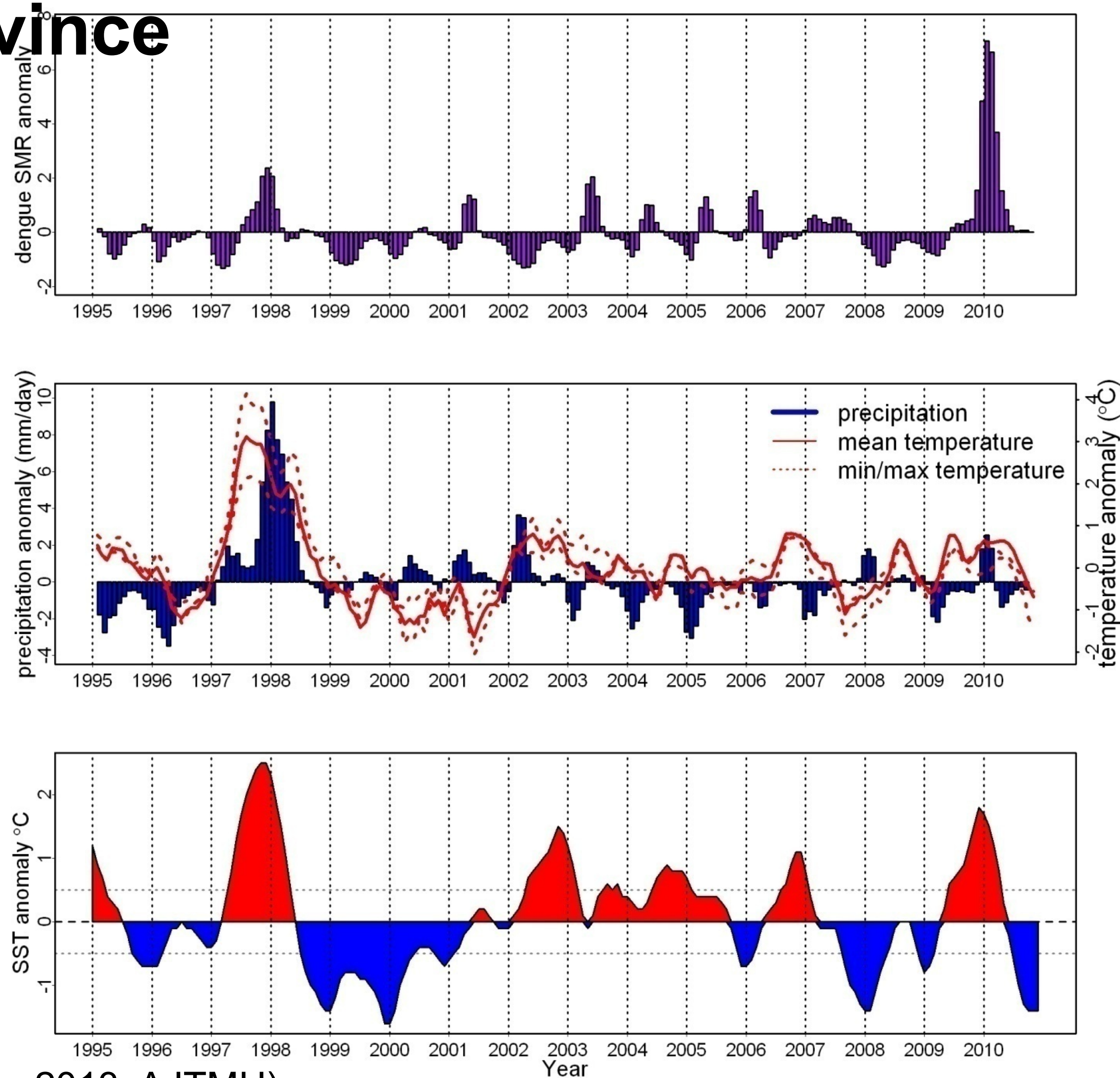
El Oro Province 1995-2010

Dengue

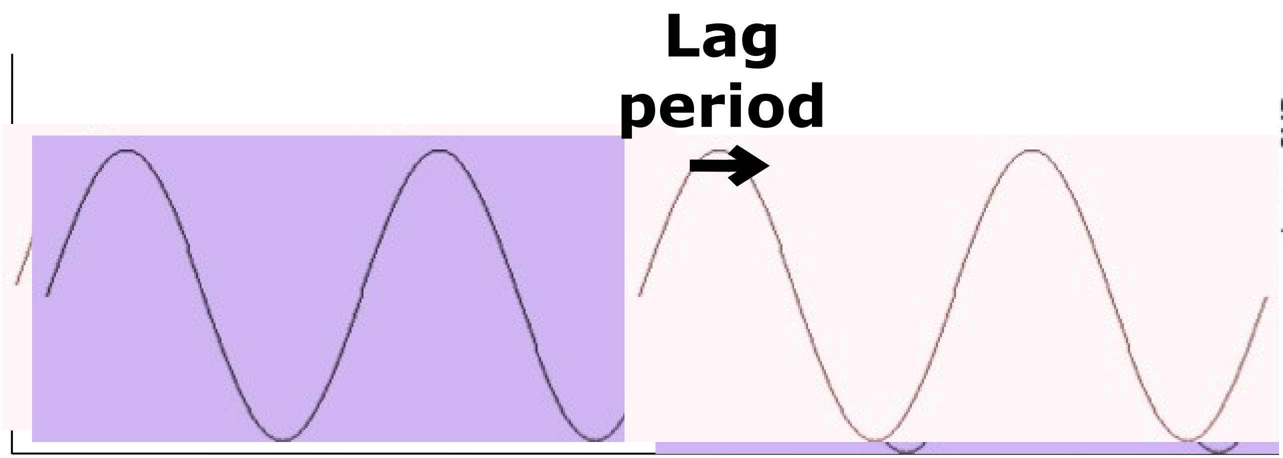
Local climate

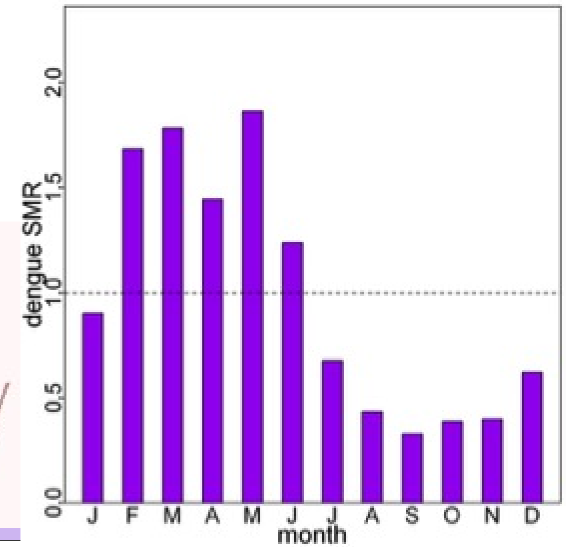
ENSO



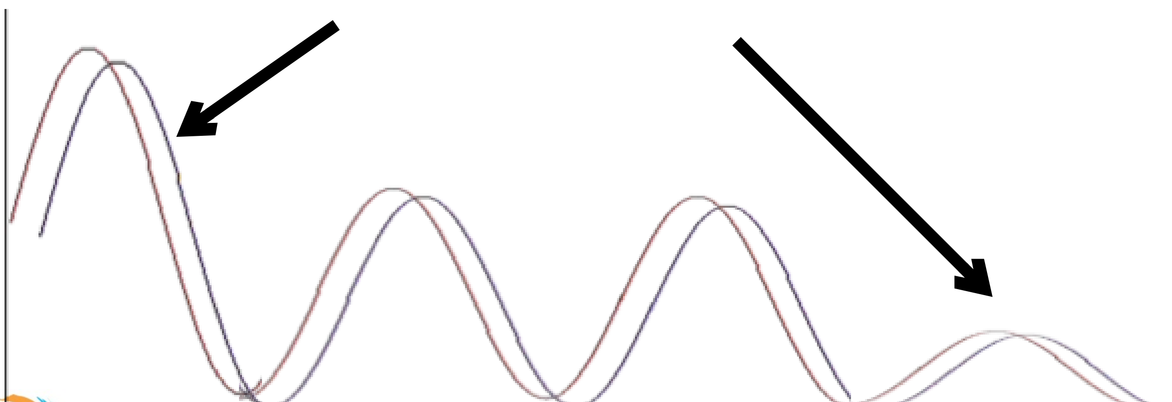
(Stewart Ibarra & Lowe, 2013, AJTMH)

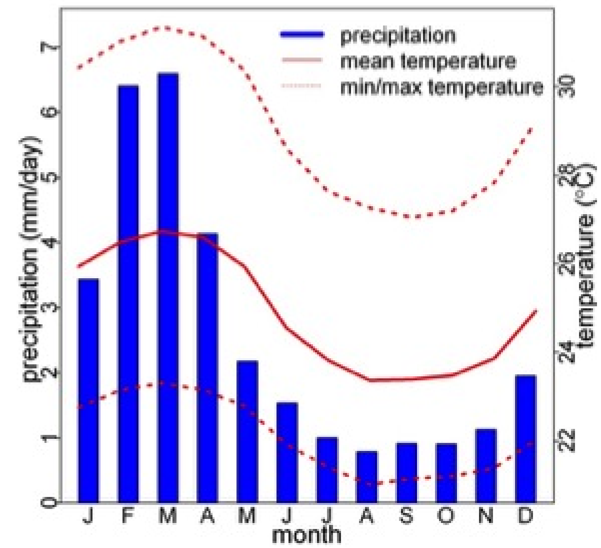
Seasonal (intra-annual) variability (average monthly incidence)





Inter-annual variability (epidemics, anomalies)





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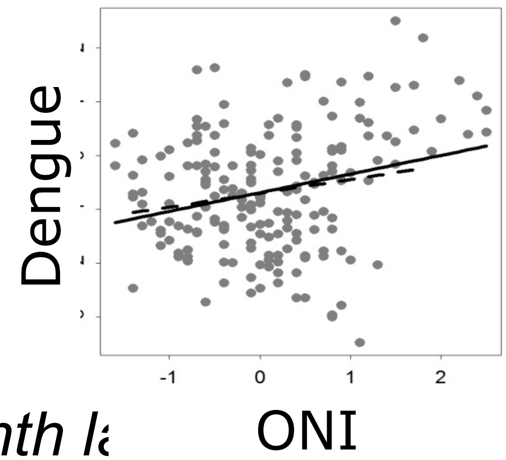
Lagged model parameters

Climate:

Oceanic Niño Index (*3 month lag*)

Minimum temperature (*2 month lag*)

Rainfall (*1 month lag*)



Non-climate:

# of serotypes circulating in the country (*3 month la*

Mosquito infestation (House Index) (*1 month lag*)

*Vector control effort was also tested

Analysis: 2 models (1995-2010, 2001-2010)

Generalized linear mixed model (negative binomial) with temporally auto-correlated random effects (monthly, yearly)

Climate & nonclimate factors drive epidemics

(Model adequacy results 2001-2010)

Model	$\log \rho_t$	DIC	R^2_{LR}
Base (Seasonal)	$\alpha+\beta_{t'(t)}$	1313.18	0.44
Climate effects	$\alpha+\beta_{t'(t)}+\sum \gamma x_{jt}$	1305.28	0.49
Non-climate effects	$\alpha+\beta_{t'(t)}+\sum \varepsilon z_{jt}$	1286.63	0.56
Climate and non-climate effects	$\alpha+\beta_{t'(t)}+\sum \gamma x_{jt}+\sum \varepsilon z_{jt}$	1276.67	0.61
Climate, random and non-climate effects	$\alpha+\beta_{t'(t)}+\sum \gamma x_{jt}+\delta_{T'(t)}+\sum \varepsilon z_{jt}$	1245.25	0.72

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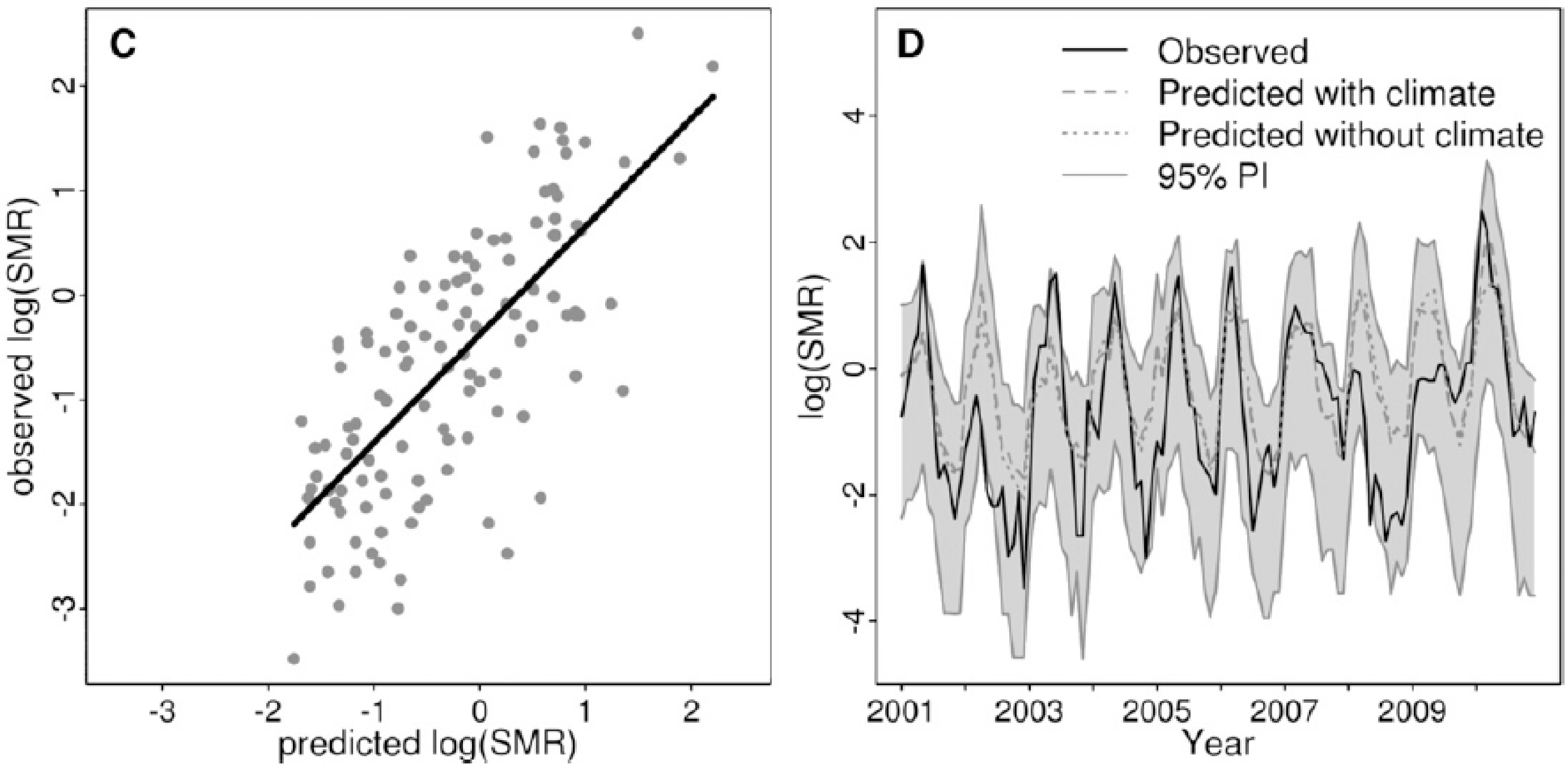
2001-2010 best fit model

(not including yearly random effects)



OPEN ACCESS Freely available online PLOS | ONE

Dengue Vector Dynamics (*Aedes aegypti*) Influenced by Climate and Social Factors in Ecuador: Implications for Targeted Control

Anna M. Stewart Ibarra[1,2,3,4*], Sadie J. Ryan[1,2,5], Efrain Beltrán[3], Raúl Mejía[4], Mercy Silva[3], Ángel Muñoz[6,7]

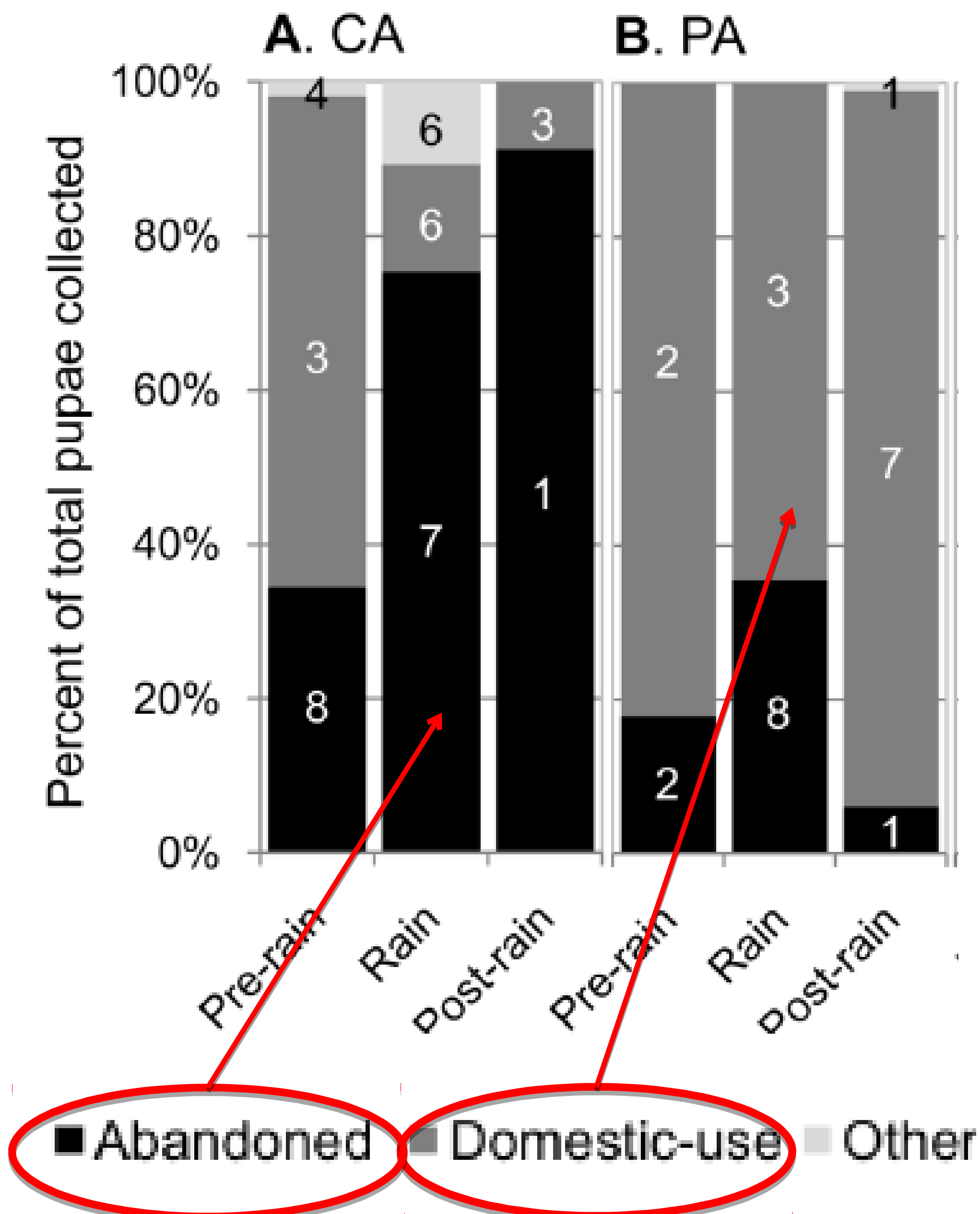
Local climate predictors varied by site

Table 3. Local climate parameters and lags in the best-fit model for *Aedes aegypti* ovitrap abundance data for both localities combined, for the central area (CA) and peripheral area (PA).

Parameters	β estimate	SE	Lower 95% CI	Upper 95% CI	*P* value
Both localities (adj. $R^2 = 69\%$)					
Intercept	2.69	1.80	−0.92	6.31	0.141
Log10(rainfall) (3 week lag)	0.27	0.07	0.13	0.40	<0.01
Minimum temperature (6 week lag)	0.25	0.09	0.07	0.42	<0.01
Relative humidity (6 week lag)	−0.03	0.01	−0.05	0.00	0.034
Maximum temperature (6 week lag)	0.17	0.08	0.02	0.32	0.028
Mean temperature (6 week lag)	−0.36	0.16	−0.68	−0.04	0.027
Locality (1 = CA, 0 = PA)	0.26	0.04	0.19	0.34	<0.01
CA (adj. $R^2 = 58\%$)					
Intercept	−0.89	0.66	−2.24	0.47	0.190
Log10(rainfall) (3 week lag)	0.38	0.09	0.19	0.58	<0.01
Minimum temperature (6 week lag)	0.13	0.03	0.07	0.19	<0.01
PA (adj. $R^2 = 61\%$)					
Intercept	0.93	1.81	−2.77	4.64	0.611
Log10(rainfall) (2 week lag)	0.14	0.09	−0.04	0.32	0.125
Minimum temperature (9 week lag)	0.10	0.04	0.02	0.19	0.021
Relative humidity (6 week lag)	−0.02	0.01	−0.04	0.01	0.136

Breeding sites vary by neighborhood

Proportion of *Ae. aegypti* pupae collected from container types in each season



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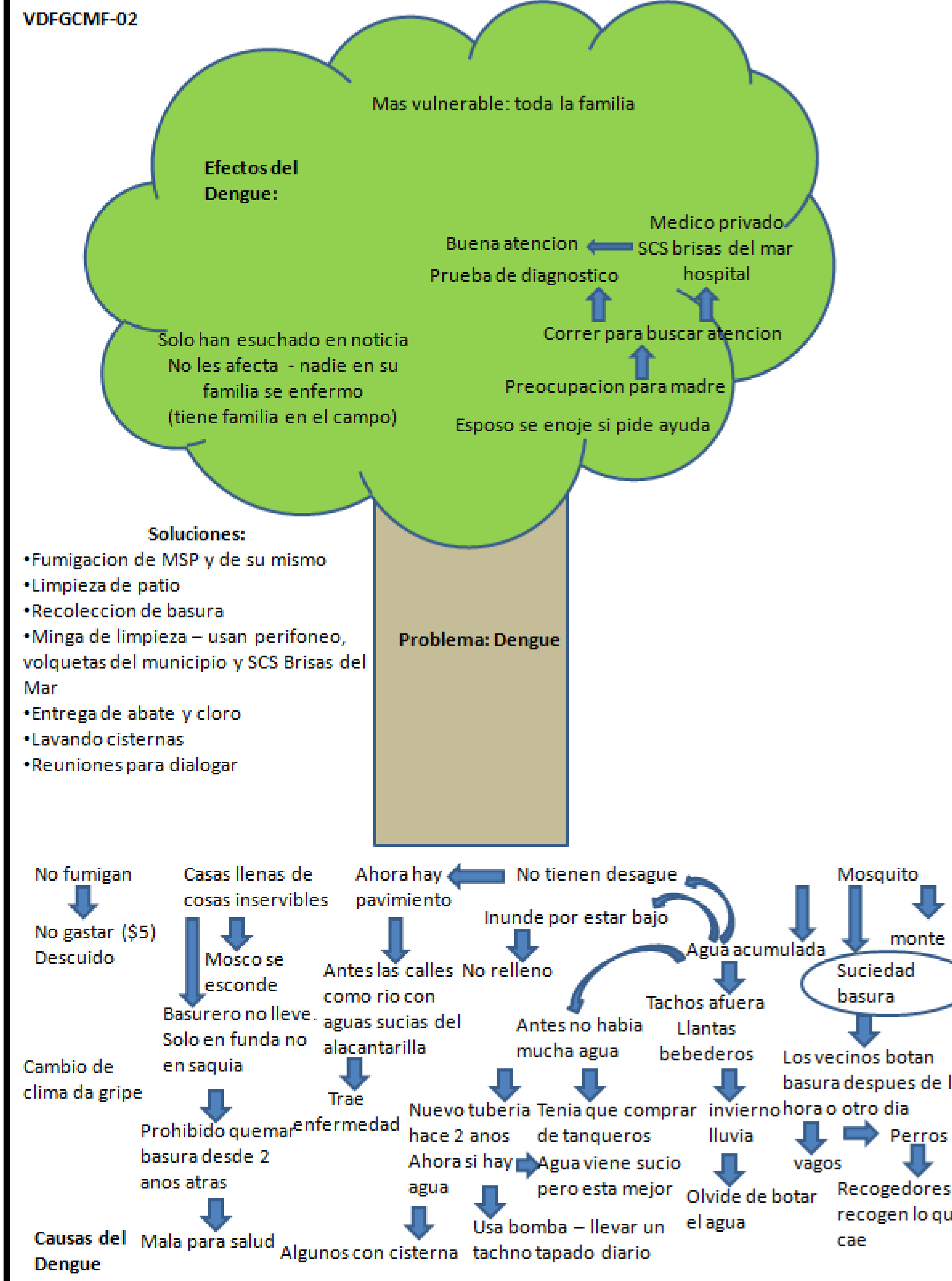
Risk factors vary seasonally

Table 2. Parameters in the top-ranked logistic models to predict the presence of *Aedes aegypti* in each season.

Parameters	β estimate	SE	OR	Lower 95% CI	Upper 95% CI	*P* value
Rainy season (n = 75)						
Intercept	−0.92	0.75				0.22
Have cist/ET & also store water	1.65	0.79	5.22	1.11	24.49	0.04
Knowledge of mosquito habitat	−1.86	0.79	0.16	0.03	0.72	0.02
Bad patio condition	1.27	0.62	3.56	1.05	12.08	0.04
Bad house condition	1.42	0.71	4.15	1.02	16.81	0.046
Older family	−1.29	0.78	0.28	0.06	1.26	0.10
Location: central neighborhood	1.02	0.65	2.77	0.77	9.88	0.12
Post rainy season (n = 75)						
Intercept	3.17	1.641				0.05
One household	−3.183	1.157	0.04	0	0.4	<0.01
Have cist/ET & also store water	3.661	1.113	38.89	4.39	344.81	<0.01
Constant access to piped water	−3.059	1.106	0.05	0.01	0.41	<0.01
Dengue is a problem	−2.905	1.58	0.05	0	1.21	0.07

Community perceptions of dengue

Perceptions govern behavior, influencing people's ability & willingness to respond to public health interventions.



(Stewart Ibarra et al, 2014 BMC Public Health)

BIOPHYSICAL

Abandoned properties
Location near periphery
Vegetation
Low elevation
Climate
Mosquitoes
Breeding sites

POLITICAL-INSTITUTIONAL

Urban planning process
Political access
Access to vector control
Access to paved streets
Strengthen regulations/policy
Access to sewerage
Access to potable water
Access to garbage collection

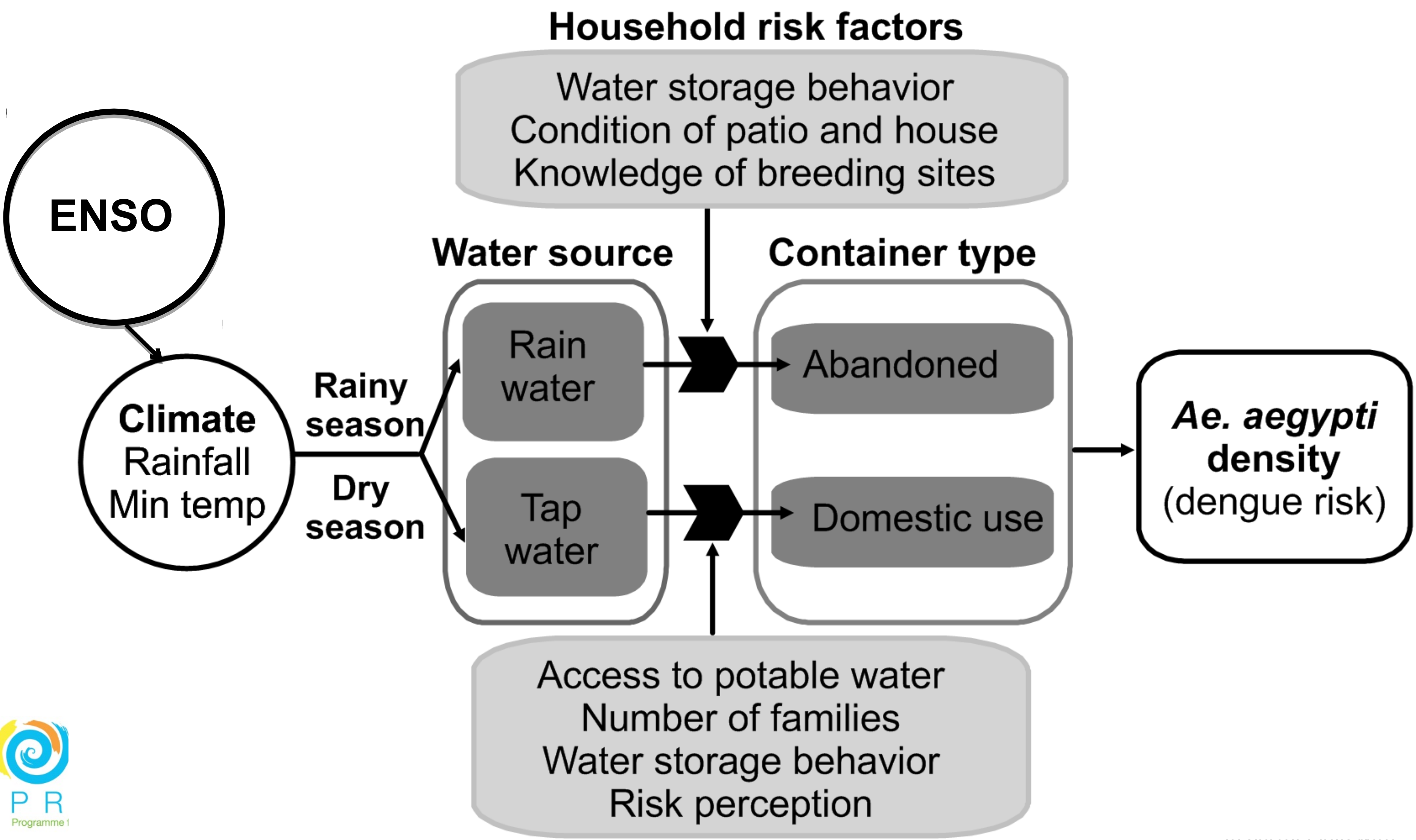
COMMUNITY & HOUSEHOLDS

Cost of vector control
Cost of water storage
Cost to elevate low-lying properties
Social cohesion (union)
Nutrition status
Immune status
Type of housing
Low income
Knowledge
Employment
Garbage disposal practices
Water storage practices
Dengue prevention practices
Attitudes towards cleanliness & prevention
General cleanliness practices

Periphery

Results:
Risk factors for dengue

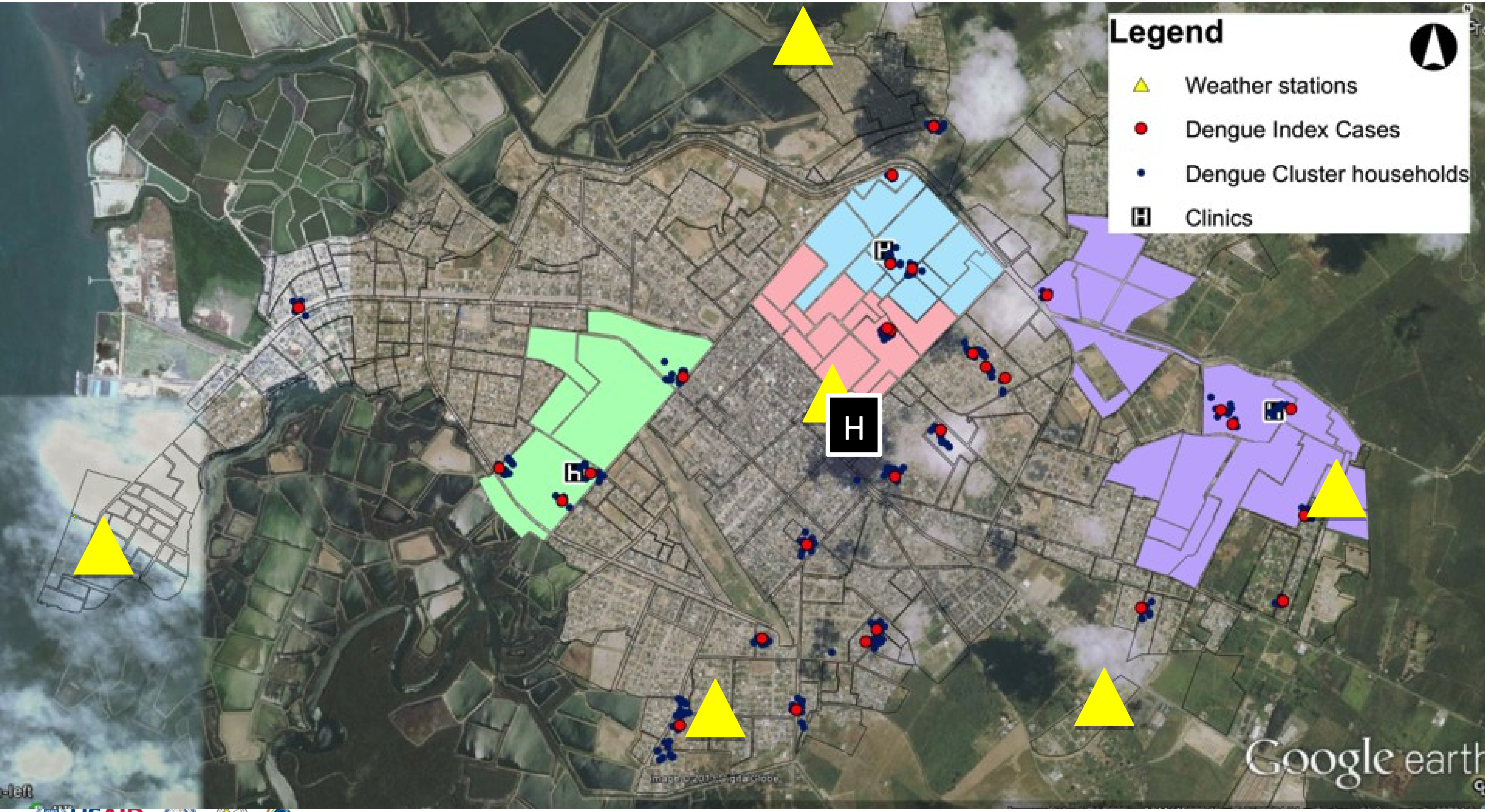
Social-ecological system for dengue



(Stewart Ibarra et al, 2013, PLOS ONE)

Capacity Strengthening in Ecuador: Partnering to improve surveillance of febrile vector-borne diseases. 2013-present.

High-resolution longitudinal spatiotemporal data on human infections, virus serotypes and genotypes, mosquito vector, human nutrition, social-ecological risk factors, microclimate data



Cold Spring Harbor Laboratory

bioRχiv beta

THE PREPRINT SERVER FOR BIOLOGY

The burden of dengue and chikungunya in southern coastal Ecuador: Epidemiology, clinical presentation, and phylogenetics from a prospective study in Machala in 2014 and 2015

Anna M. Stewart-Ibarra, Aileen Kenneson, Christine A. King, Mark Abbott, Arturo Barbachano-Guerrero, Efrain Beltran-Ayala, Mercy J. Borbor-Cordova, Washington B. Cardenas, Cinthya Cueva, Julia L. Finkelstein, Christina D. Lupone, Richard G. Jarman, Irina Maljkovic Berry, Saurabh Mehta, Mark Polhemus, Mercy Silva, Sadie J. Ryan, Timothy P. Endy

Social-Ecological Factors And Preventive Actions Decrease The Risk Of Dengue Infection At The Household-Level: Results From A Prospective Dengue Surveillance Study In Machala, Ecuador

Aileen Kenneson, Efrain Beltran-Ayala, Mercy J. Borbor-Cordova, Mark E. Polhemus, Sadie Ryan, Timothy P. Endy, Anna Stewart-Ibarra

doi: https://doi.org/10.1101/136382

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In-situ Vector Dynamics in a High Burden Region in Ecuador

NSF Zika Rapid; 2016-2017. PI: A Stewart; Co-PIs: Ryan, Endy, Neira

Effects of temperature on vector-borne disease transmission: integrating theory with empirical data

NSF/NIH EEID; 2015-2020; PI: Erin Mordecai, Stanford University

- 3 year cohort study
- 240 households, 4 sites
- ibuttons for temp, RH
- Adult mosquito abundance
- Household risk factors
- Dengue & zika prevalence and incidence in mosquitoes and humans

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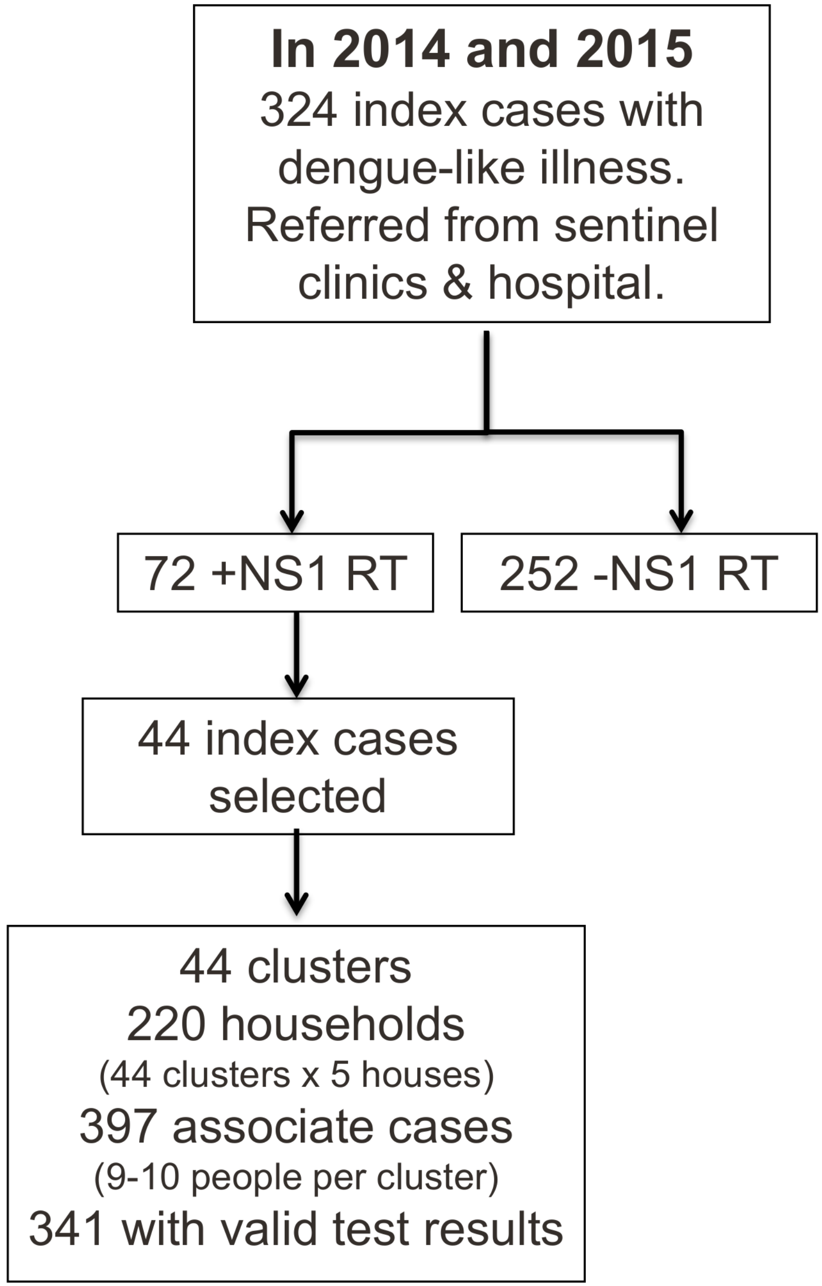
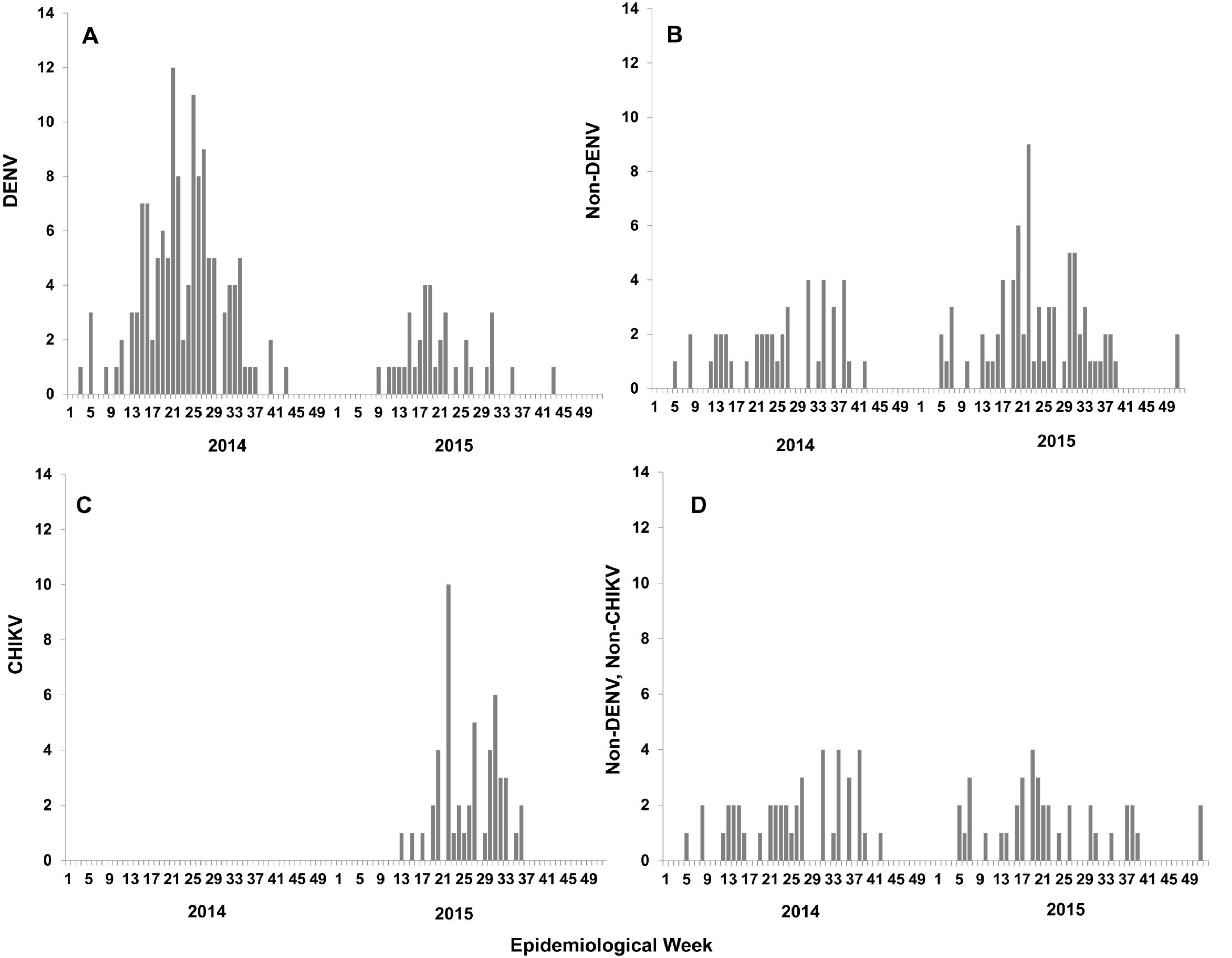

In 2014 and 2015
324 index cases with dengue-like illness. Referred from sentinel clinics & hospital.
72 +NS1 RT
252 -NS1 RT
44 index cases selected
44 clusters
220 households
(44 clusters x 5 houses)
397 associate cases
(9-10 people per cluster)
341 with valid test results

Key results

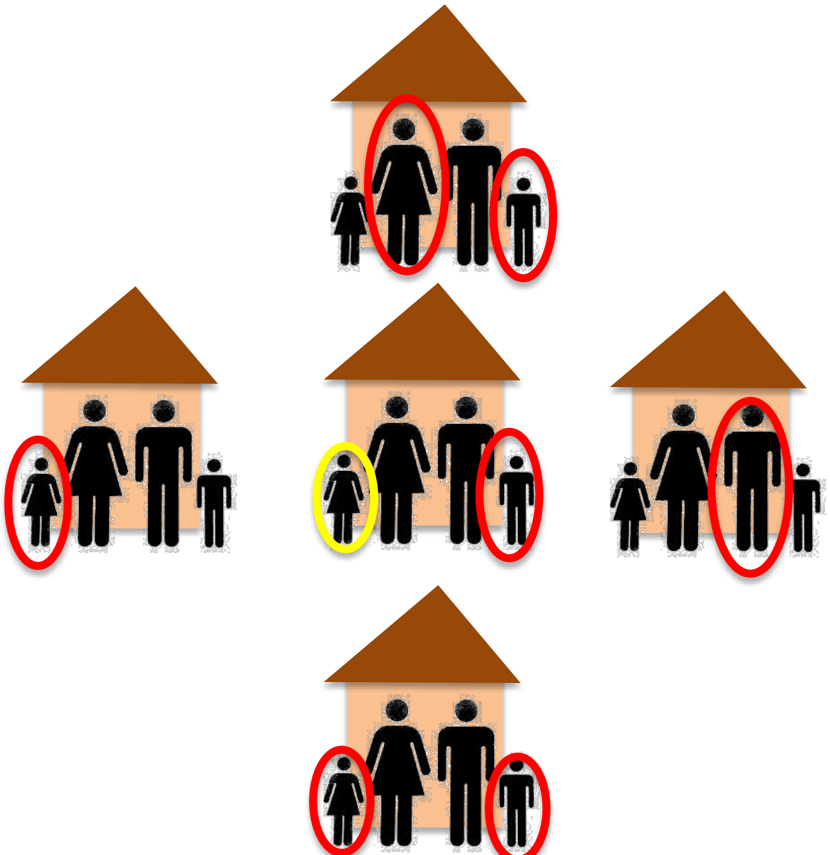
- Strengthened local arbovirus surveillance capacities
- Fine-scale data on the spatial and temporal dynamics of disease transmission and climate across the city.
- Characterization of infections (i.e., symptoms, serotypes, serology)
- Prevalence of asymptomatic and symptomatic arbovirus infections in the community.
- Phylogenetic analysis of viruses moving through the region
- Household and individual-level risk factors
- Detection of the emergence of CHIKV in Machala in 2015 and ZIKV in 2016



A
B
C
D
DENV
Non-DENV
CHIKV
Non-DENV, Non-CHIKV
0
2
4
6
8
10
12
14
1 5 9 13 17 21 25 29 33 37 41 45 49 1 5 9 13 17 21 25 29 33 37 41 45 49
2014
2015
Epidemiological Week

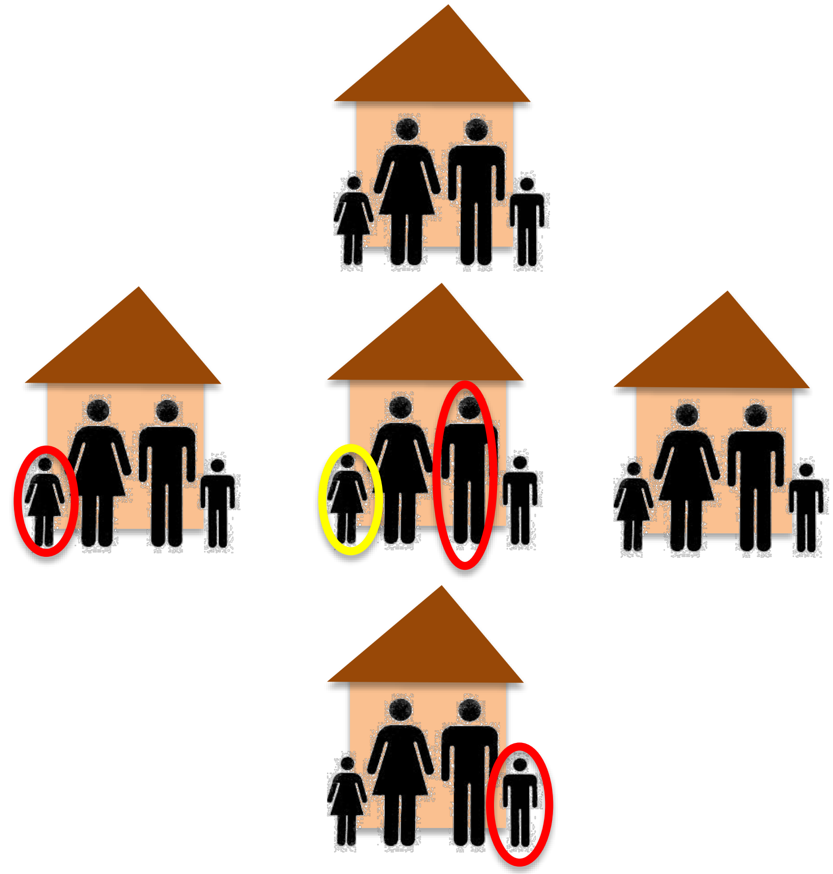
Cluster prevalence estimates for DENV

2014



7 acute/recent DENV associate cases per acute DENV index case (34% of associates).

2015



2-3 acute/recent DENV associate cases per acute DENV index case (13% of associates).

Improved seasonal climate forecasts, El Niño forecasts, and new mathematical approaches for better dengue forecasts.

Long-Lead El Niño forecast information to support public health decision making

D. Petrova[1], S.J. Koopman[2], R. Lowe[1], A. Stewart-Ibarra[3], X. Rodó[1]

(1) Catalan Institute of Climate Science (IC3), Barcelona, Spain (2) VU Amsterdam, Netherlands (3) SUNY Upstate Medical University, New York, USA University

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Predictability of December–April Rainfall in Coastal and Andean Ecuador

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National Institute of Meteorology and Hydrology, and Observatorio Latinoamericano de Eventos Extraordinarios, and Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador

Anthony G. Barnston

International Research Institute for Climate and Society, Palisades, New York

Ángel G. Muñoz

International Research Institute for Climate and Society, Palisades, New York, and Centro de Modelado Científico, Universidad del Zulia, and Observatorio Latinoamericano de Eventos Extraordinarios, Maracaibo, Venezuela

Phenomenological forecasting of disease incidence using heteroskedastic Gaussian processes: a dengue case study

Leah R. Johnson* Robert B. Gramacy† Jeremy Cohen‡

Erin Mordecai§ Courtney Murdock¶ Jason Rohr‖ Sadie J. Ryan**

Anna M. Stewart-Ibarra†† Daniel Weikel‡‡

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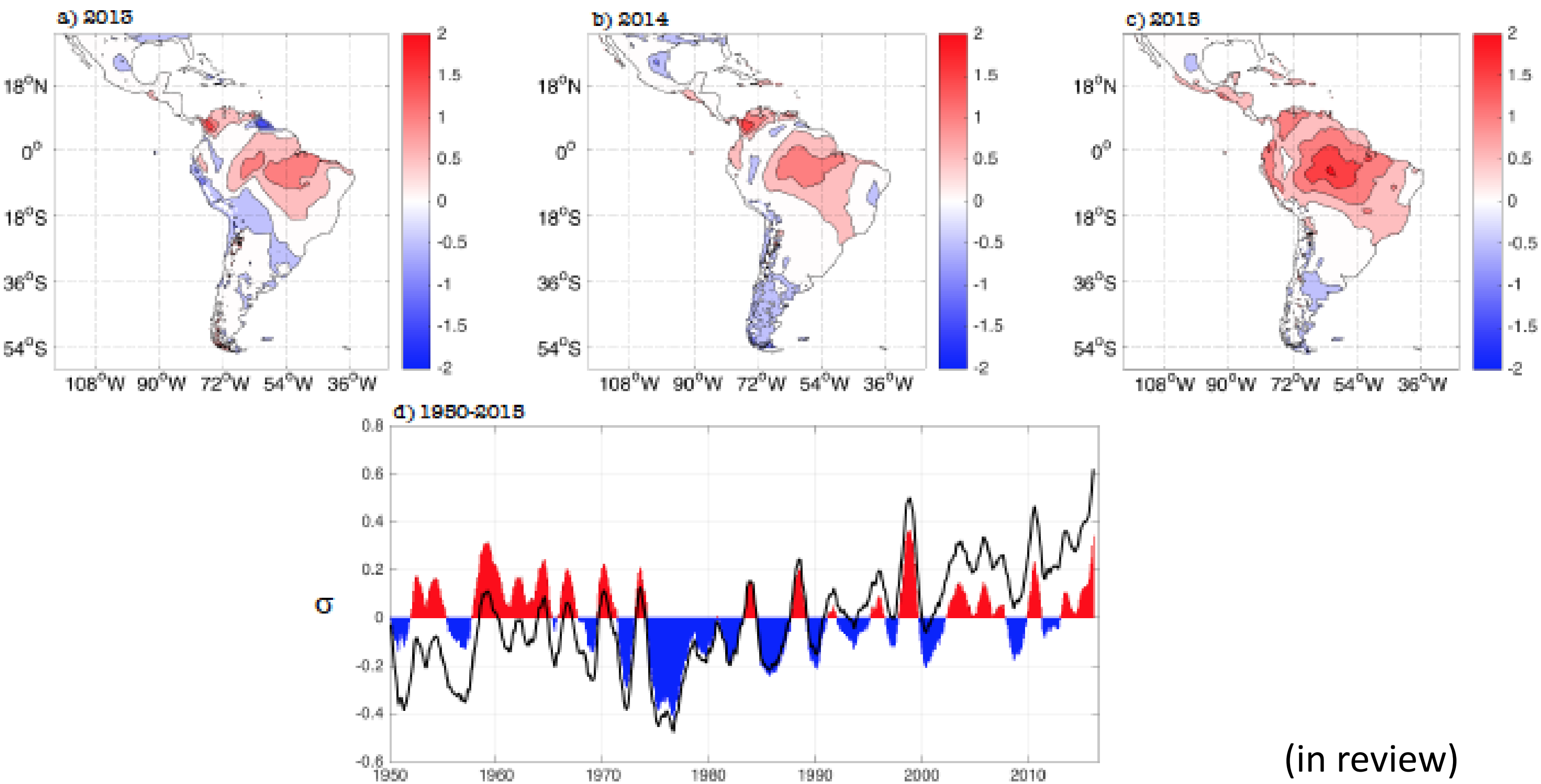
Could the recent zika epidemic have been predicted?

Ángel G. Muñoz[1*], Madeleine C. Thomson[2], Anna M. Stewart-Ibarra[3], Gabriel Vecchi[4], Xandre Chourio[5], Patricia Nájera[6], Zelda Moran[7], Xiaosong Yang[8]

Above-normal suitable conditions for the occurrence of the zika epidemic at the beginning of 2015 could have been successfully predicted for several zika hotspots, and in particular for Northeast Brazil: the heart of the epidemic.



(in review)

Early warning systems that use climate information are a strategy to better manage and prevent epidemics.

1. Bring together the climate-health sector and local communities.
2. Provide the evidence base that climate affects epidemics/outbreaks.
3. Strengthen local disease, mosquito, and climate surveillance systems. Match the spatial and temporal resolution of data.
4. Strengthen climate forecast models.
5. Create models to forecast epidemics using climate information.
6. Translate the models into useful/operational tools for the public health sector, which reflect the local reality.

Lessons learned for work on climate and health

- This topic brings people out of their comfort zones and cuts across disciplinary and institutional silos.
- Requires strong political will and buy-in from authorities.
- Requires a long-term commitment. This is a dynamic and iterative process.
- Need to define the priorities, common objectives and expected outputs.

Lessons learned for work on climate and health

- Need to create tailored climate and health data: define temporal and spatial scales, data format.
- Need to establish data sharing protocols and avenues for dialogue (forums)
- Capacity building between both sectors (2 way) is important to strengthen the collaboration.
- **Providing scientific evidence of the effects of climate on health is an important early win.**

It is important to have strong institutional partners and a team of collaborators who are engaged in the co-development of climate services.

- Research is responsive by national strategic priorities.
- Need continuous engagement through formal and informal communication.
- Build trust, relationships, reputation. Face time is critical.
- Open to new ideas and non-expert input, especially in cross-cultural settings.
- Flexible to adjust as needed when change arise in the study.
- Willing to embrace ambiguity and complexity.
- Willing to examine personal and cultural biases.
- Active team participants
- Willing to express their values to the group and understand the role and work of other participants.
- Experience working in an interdisciplinary team, or have patience and willingness to learn the process.
- Collaborative, exhibiting respect, humbleness, and trust for the people and process.
- Ability to clearly communicate.

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National Institute of Meteorology
Ministry of Environment
World Health Organization

Public-Private Partnerships
Pharmaceuticals (vaccines, diagnostics)
Insecticides, mosquito surveillance traps

Biomedical science
Medicine
Virology
Immunology
Epidemiology
Public health
Psychology

Social science
Sociologists
Political scientists
Communications experts

Funding & Regulatory agencies
NSF, NIH, DoD, FDA, IAI, Gates
SENESCYT, ENFARMA, ARCSA

Civil society actors
Community leaders
NGOs
Media
Artists

Biophysical science
Climate science
Modelers (GIS, statistics)
Ecology
Entomology

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Programme for Building Regional Climate Capacity in the Caribbean

This study is being conducted by the Caribbean Institute for Meteorology and Hydrology (CIMH) in collaboration with the State University of New York Upstate Medical University (SUNY UMU) through the United States Agency for International Development's (USAID) Programme for Building Regional Climate Capacity in the Caribbean (BRCCC Programme) with funding made possible by the generous support of the American people.

More information about the BRCCC Programme is available at: rcc.cimh.edu.bb/brccc

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Thanks!

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